Title of the Invention

Information Recording Disc and Information Recording/Reproducing Apparatus

Background of the Invention

Field of the Invention

The present invention relates to an information recording disc and an information recording/reproducing apparatus.

Description of the Prior Art

Conventionally, an information recording disc and an apparatus for recording and reproducing an information signal using the information recording disc have been suggested. As such an information recording disc, there can be exemplified a so-called optical disc, a magneto-optical disc, a hard disc, and the like.

The so-called magneto-optical disc includes, as shown in Fig. 1, a signal recording layer (MO film) 101 which is sandwiched by dielectric films 102 and 103 having an enhancement effect. The signal recording layer 101 and the dielectric films 102, 103 are protected by a protection film 104 and the substrate 105 and a cover material, respectively, and they are not exposed outside. Accordingly, in this magneto-optical disc, there is no danger of contact or collision of the signal recording layer 101 and the dielectric films 102, 103 with an objective lens or a magnetic head of an optical pick-up apparatus, and there is no need of countermeasures for

preventing such contacts or collisions.

Moreover, in the so-called hard disc, when reproducing an information signal recorded or recording an information signal onto the information recording disc, as shown in Fig. 2, it is preferable that the signal recording layer 101 formed on the substrate 105 of the information recording disc be in the vicinity of the magnetic head 106, requiring no optical condition. Accordingly, a lubrication film 107 coated with a thin film of a lubricant is formed between the magnetic head 106 and the information recording disc. The lubricant often used contains fluoride for its characteristics. The magnetic head 106 is mounted on and supported by a slider 108.

Recently, in the case of optical disc also, as in the hard disc, an optical disc apparatus in which the signal recording layer is in the proximity with the objective lens of the optical pick-up apparatus has been developed. As such an optical disc, a so-called "optical hard disc apparatus" and a "near-field optical disc apparatus" have been suggested. In the optical hard disc apparatus, an object lens is mounted and supported by a slider. In the near-field optical disc apparatus, an objective lens have a numerical aperture (NA) not smaller than 1 although not having the configuration of mounting the objective lens by the slider.

As shown in Fig. 3, in the "near-field optical disc apparatus", the objective lens is a so-called solid immersion lens (SIL) 110 whose first surface is arranged in the proximity of the surface portion of the information recording disc and the first surface of the SIL 110 is arranged in a so-called near-field region with respect to that surface

portion.

An information recording disc used in such an "optical hard disc apparatus" includes, as shown in Fig. 4, a reflection film 109, a second dielectric film 103, a signal recording layer 101, and a first dielectric film 102 successively arranged from the side of the substrate 105. The information recording disc having the four-layered films consisting of the reflection film 109, the second dielectric film 103, the signal recording layer 101, and the first dielectric film 102 is designed so as to obtain the enhancement effect for increasing a recording data contrast for a light incident vertically to the substrate 105.

In the information recording/reproducing apparatus configured as the so-called "optical hard disc apparatus", the signal recording layer of the information recording disc is in the proximity of the objective lens of the optical pick-up apparatus and there is a possibility that the signal recording layer collides into the objective lens. Here, when the signal recording layer is coated with a lubricant, if there is any film thickness irregularity in the coating, this causes irregularities in the optical characteristic. Accordingly, it is necessary to reduce the film thickness irregularities.

Moreover, as the lubricant for the near-field optical disc apparatus, a fluoride-system material is not appropriate because it has a low refractive index. Thus, in the near-field optical disc apparatus, it is difficult to select an appropriate lubricant.

Moreover, in the optical hard disc apparatus, it is preferable that the first surface of the objective lens including a boundary in the proximity be coated with an

anti-reflection coating (AR coating), so that fluctuations of a distance between the information recording disc and the objective lens will not affect the optical characteristics.

However, since the objective lens is in the proximity of the information recording disc, the objective lens easily collide into the information recording disc and such collision may peel off the anti-reflection coating. If the anti-reflection coating is peeled off from the objective lens, the optical characteristic of the entire apparatus is changed, disabling a preferable recording/reproducing of an information signal. Thus, it is difficult to select a film formation material of the anti-reflection coating as well as to handle the coating.

Furthermore, in the aforementioned configuration, among a light flux applied to the information recording disc, a component having a high numerical aperture (NA) cannot reach the signal recording layer easily. That is, assume that an air film between the information recording disc and the SIL is a thin film having a refraction index (n) of 1, the calculation result of dependency of the reflectance of the first dielectric film on the incident angle when incident via an air gap having a thickness t from the SIL as an optical part having a refractive index (n) of 1.8 shows that different incident angles corresponding to the numerical apertures fluctuate the intensity of the light incident into the first dielectric film as shown in Fig. 5. Furthermore, when the optical system is designed for an air gap having a thickness of 50 nm, the fluctuation of the air gap thickness drastically changes the reflectance, easily causing fluctuation of the

light energy distribution.

Moreover, as shown in Fig. 6 and Fig. 7, a calculation result of the modulation transfer function (MTF) shows that increase of the air gap thickness between the information recording disc and the SIL easily deteriorates the MTF.

Furthermore, in the information recording disc having the film configuration shown in Fig. 4, the outermost surface opposing to the SIL is a film made from $ZnS-SiO_2$. This $ZnS-SiO_2$ is a very soft material and is easily damaged when a collision with the SIL occurs. In the hard disc, polishing is performed to improve the surface characteristic. However, when the outermost surface is made from a soft material such as $ZnS-SiO_2$, polishing cannot be performed.

Moreover, in this information recording disc, an abrasion phenomenon is easily caused during an information recording, which causes a problem that the film is removed and rubbish is easily generated.

Summary of the Invention

It is therefore an object of the present invention to provide an information recording disc having a film configuration that can easily be prepared and capable of having a sufficient margin for a thickness change of an air gap between the disc and a focusing element when recording/reproducing an information signal using the so-called near-field technique as well as minimizing a data amount lost when a collision with the focusing element occurs. The present invention also provides an

information recording/reproducing apparatus for recording/reproducing an information signal using the information recording disc.

In order to achieve the aforementioned object, the present invention provides an information recording disc including a signal recording layer for use in an information recording/reproducing apparatus having a light source for emitting a light flux and a focusing element for focusing the light flux to be applied to the signal recording layer, wherein the signal recording layer is positioned approximately on a surface portion facing to the focusing element and the surface portion is coated with an anti-reflection coating film.

According to another aspect of the present invention, the information recording disc including a signal recording layer for use in an information recording/reproducing apparatus having a light source for emitting a light flux and a focusing element for focusing the light flux to be applied to the signal recording layer, wherein the distance between the focusing element and a surface portion facing to the focusing element is not greater than a wavelength of the light flux, and wherein the surface portion facing to the focusing element is coated with an anti-reflection coating film.

Moreover, the present invention provides an information recording/reproducing apparatus comprising: a rotation mechanism for holding and rotating an information recording disc; a light source; and a focusing element for focusing a light flux emitted from the light source so as to be applied to a signal recording layer of the information recording disc.

In this information recording/reproducing apparatus, the information recording disc is used in such a manner that a distance between the focusing element and the surface portion facing to this focusing element is not greater than a wavelength of the light flux, and the information recording disc includes an anti-reflection coating film formed on the surface portion facing to the focusing element.

Brief Description of the Drawings

Fig. 1 is a cross sectional view showing a configuration of a conventional magneto-optical disc and an objective lens as an essential portion of an information recording/reproducing apparatus.

Fig. 2 is a cross sectional view showing a configuration of a conventional hard disc and a magnetic head as an essential portion of an information recording/reproducing apparatus.

Fig. 3 is a cross sectional view showing a configuration of a conventional near-field optical disc and a SIL (solid immersion lens) as an essential portion of an information recording/reproducing apparatus.

Fig. 4 is a cross sectional view shown a configuration of a conventional near-field optical disc.

Fig. 5 graphically shows the relationship between an air gap and a reflectance in the aforementioned conventional information recording disc and the information recording/reproducing apparatus.

Fig. 6 graphically shows the relationship between an air gap thickness and a focus position where the reproduction signal carrier level becomes maximum in the aforementioned conventional information recording disc and the information recording/reproducing apparatus.

Fig. 7 graphically shows the relationship between the air gap thickness and the MTF (modulation transfer function) at the focus position shown in Fig. 6 where the reproduction signal carrier level becomes maxim in the aforementioned conventional information recording disc and the information recording/reproducing apparatus.

Fig. 8 is a cross sectional view showing a configuration of an information recording disc and a focusing element as an essential portion of an information recording/reproducing apparatus according to the present invention.

Fig. 9 graphically shows the relationship between the air gap thickness and the reflectance in the information recording disc and the information recording/reproducing apparatus shown in Fig. 8.

Fig. 10 is a cross sectional view showing another example of the configuration of the aforementioned information recording disc and the focusing element as an essential portion of the information recording/reproducing apparatus.

Fig. 11 graphically shows the relationship between the air gap thickness and the reflectance in the information recording disc and the information recording/reproducing apparatus shown in Fig. 10.

Fig. 12 is a side view showing a support structure of the focusing element in the

aforementioned information recording/reproducing apparatus.

Fig. 13 graphically shows the relationship between the air gap thickness and the focus position where the reproduction signal carrier level becomes maximum in the aforementioned information recording disc and the information recording/reproducing apparatus.

Fig. 14 graphically shows the relationship between the air gap thickness and the MTF at the focus position shown in Fig. 13 where the reproduction signal carrier level becomes maximum in the aforementioned information recording disc and the information recording/reproducing apparatus.

Fig. 15 graphically shows the relationship between the air gap thickness and the focus position where the reproduction signal carrier level becomes maximum in the aforementioned information recording disc and the information recording/reproducing apparatus.

Fig. 16 graphically shows the relationship between the air gap thickness and the MTF at the focus position shown in Fig. 15 where the reproduction signal carrier level becomes maximum in the aforementioned information recording disc and the information recording/reproducing apparatus.

Fig. 17 graphically shows the relationship between the air gap thickness and the phase characteristic in the aforementioned information recording disc and the information recording/reproducing apparatus.

Fig. 18 graphically shows the relationship between the air gap thickness in an

information recording disc having a single-layered anti-reflection coating and the focus position where the reproduction signal carrier level becomes maximum.

Fig. 19 graphically shows the relationship between the air gap thickness in an information recording disc having a single-layered anti-reflection coating and the MTF at the focus position shown in Fig. 18 where the reproduction signal carrier level becomes maximum.

Fig. 20 graphically shows the relationship between the air gap thickness and the phase characteristic in an information recording disc having a single-layered anti-reflection coating.

Fig. 21 graphically shows the relationship between the air gap thickness and the focus position where the reproduction signal carrier level becomes maximum in an information recording disc having a coating not satisfying the anti-reflection condition.

Fig. 22 graphically shows the relationship between the air gap thickness and the MTF in an information recording disc having a coating not satisfying the anti-reflection condition.

Fig. 23 graphically shows the relationship between the air gap thickness and the MTF in an information recording disc having a coating not satisfying the anti-reflection condition.

Detailed Description of Preferred Embodiments

Description will now be directed to an embodiment of the present invention

with reference to the attached drawings.

As shown in Fig. 8, this embodiment is configured as an information recording disc for recording/reproducing an information recording disc according to the present invention using the so-called near-field technique. Moreover, in this embodiment, the recording/reproducing apparatus according to the present invention is configured as an information recording/reproducing apparatus for recording/reproducing an information onto/from an information recording disc using the so-called near-field technique.

As shown in Fig. 8, this information recording disc is configured as a phase change type disc (phase change medium) including a reflection film 2 made from aluminum (Al), a second dielectric film 3, a signal recording layer 4, and a first dielectric film 5 successively formed from the side of the substrate 1. The reflection film 2, the second dielectric film 3, the signal recording layer 4, and the first dielectric layer 5 constitute the enhancement condition with respect to a light focus component vertically incident to the substrate 1, i.e., the enhancement condition at the beam west. Furthermore, the first dielectric film 5 is coated with an anti-reflection coating consisting of a third, a fourth, and fifth dielectric film 6, 7, 8. The anti-reflection coating consisting of the third, the fourth, and the fifth dielectric film 6, 7, 8 enables to obtain an anti-reflection condition, with respect to the first dielectric film 5, for the light incident from a focusing element, i.e., the SIL (solid immersion lens) 10 and having an angle against the surface of the information recording disc.

When the wavelength used is 650 nm, the first dielectric film 5 is made from ZnS-SiO_2 having a thickness of 100 nm and a refractive index (n) of 2.16; the second dielectric film 3 is made from ZnS-SiO_2 having a thickness of 40 nm and a refractive index (n) of 2.16; the third dielectric film 6 is made from SiO_2 having a thickness of 15 nm and a refractive index (n) of 1.47; the fourth dielectric film 7 is made from SiN having a thickness of 50 nm and a refractive index (n) of 2.0; and the fifth dielectric film 8 is made from SiO_2 having a thickness of 200 nm and a refractive index (n) of 1.47. The signal recording layer 4 is made from $Ge_2Sb_2Te_5$ having a thickness of 20 nm and a refractive index (n) of 3.9.

Fig. 9 shows calculation results of incident angle dependency of the reflectance of the first dielectric film 5 when the air film 9 is considered to have a refractive index (n) of 1 and an optical part having a refractive index (n) of 1.8 is used via the air gap 9 having a thickness of t. When the air gap 9 has a thickness of 50 nm, for example, the anti-reflection coating function in such a way that the reflectance of the first dielectric film 5 is not greater than 10 % for the light ray of the incident angle up to 50°. This shows that in this information recording disc, the coupling efficiency is increased and the coupling efficiency change is gentle for the change of the air gap thickness.

Furthermore, in this information recording disc, the outermost surface facing to the SIL 10 is made from SiO_2 and the film is not easily damaged even when the SIL 10 collides into the outermost surface.

In the convention information recording disc, the outermost surface is made from ZnS-SiO_2 which is soft and it has been difficult to perform burnishing. In contrast to this, in the information recording disc according to the present embodiment, the outermost surface is made from SiO_2 and it is possible to perform burnishing. Accordingly, it is possible to remove any protrusions made by an abnormal discharge in the sputtering when forming the signal recording layer 4.

Furthermore, since the fifth dielectric film 8 forming the outermost surface has a thickness not less than 100 nm, a gentle margin is available in burnishing.

Moreover, in this information recording disc, even when the SIL 10 as the focusing element collides into the surface portion, causing a peel off, only the data of the portion where the anti-reflection coating is peeled off is lost, which is by far less than the data loss when SIL 10 has the anti-reflection coating which is peeled off. On the other hand, when the anti-reflection coating film is formed on the side of the SIL 10 and the film is peeled off, the optical condition is changed for a data recording/reproducing over the entire surface of the information recording disc.

When the signal recording layer is a magneto-optical (MO) recording film, the information recording disc has a film configuration as shown in Fig. 10, including a reflection film 2, a second dielectric film 3, a signal recording layer 4, and a first dielectric film 5 successively formed from the side of the substrate 1. The reflection film 2, the second dielectric film 3, the signal recording layer 4, and the first dielectric film 5 constitute the enhancement condition for the light flux component vertically

incident into the substrate 1, i.e., the enhancement condition at the beam west. Furthermore, the first dielectric film 5 is coated with an anti-reflection coating consisting of a third, a fourth, and a fifth dielectric film 6, 7, 8. The anti-reflection coating consisting of the third, the fourth, and the fifth dielectric film 6, 7, 8 constitutes the anti-reflection condition, with respect to the first dielectric film 5, for the light ray incident from the focusing element, i.e., the SIL (solid immersion lens) 10 and having an angle against the surface of the information recording disc.

When the wavelength used is 650 nm, the first dielectric film 5 is made from SiN having a thickness of 100 nm and a refractive index (n) of 2.00; the second dielectric film 3 is made from SiN having a thickness of 20 nm and a refractive index (n) of 2.0; the third dielectric film 6 is made from SiO_2 having a thickness of 10 nm and a refractive index (n) of 1.47; the fourth dielectric film 7 is made from SiN having a thickness of 50 nm and a refractive index (n) of 2.0; and the fifth dielectric film 8 is made from SiO_2 having a thickness of 200 nm and a refractive index (n) of 1.47. The signal recording layer 4 is made from TbFeCo having a thickness of 20 nm and a refractive index (n) of 3.13 and GbFeCo having a thickness of 4 nm and a refractive index (n) of 2.86.

Fig. 11 shows a calculation result of the incident angle dependency of the reflectance of the first dielectric film 5 when the air film 9 is considered to have a refractive index (n) of 1, an optical part having a refractive index (n) of 1.8 is used, and the air gap 9 having a thickness of t intervenes. When the air gap 9 has a thickness

of 50 nm, for example, the anti-reflection coating makes the reflectance of the first dielectric film 5 be not greater than 10 % for light rays of the incident angle up to 50°. This result shows that in the information recording disc, the coupling efficiency is increased and the change of the coupling efficiency is gentle for the change of the air gap thickness.

Furthermore, in this information recording disc, the outermost surface portion opposing to the SIL 10 is made from SiO_2. That is, even when the SIL 10 collides into the outermost surface, the signal recording layer 4 weak to oxidation will not easily be exposed outside.

In this information recording disc having the outermost surface made from SiO_2, it is possible to perform burnishing. Accordingly, it is possible to remove any protrusions formed due to an abnormal discharge during sputtering for forming the signal recording layer 4.

Furthermore, since the fifth dielectric film 8 serving as the outermost surface has a thickness not less than 100 nm, a gentle margin is available for burnishing.

Moreover, in this information recording disc, when the SIL 10 as the focusing element collides into the surface portion, causing a peel-off, the data loss occurs only in the portion where the anti-reflection coating has been peeled off unlike the case when the anti-reflection coating film is formed at the side of SIL 10 and the film has been peeled off.

It should be noted that in the aforementioned embodiments, explanation has

been given on a specific example when the wavelength used is 650 nm, the air film has a thickness of 50 nm, and the focusing element (SIL 10) has a refractive index (n) of 1.8. However, the information recording disc according to the present invention is not to be limited to these conditions. Moreover, in the aforementioned embodiments, explanation has been given on a configuration having a signal recording layer as a phase change film and a magneto-optical recording film. However, the information recording disc according to the present invention is not to be limited to the configuration of such a recording film and may have an information recording layer dedicated for a signal reproduction.

The information recording/reproducing apparatus according to the present invention includes a rotation/operation mechanism for holding and rotating/operating the aforementioned information recording disc. Moreover, this information recording/reproducing apparatus includes a light source and a SIL (solid immersion lens) as a focusing element for focusing the light flux emitted from the light source and applying it to a signal recording layer. The SIL is an approximately hemispheric lens having a flat portion facing to the information recording disc, so that the light flux incident from the spherical portion is applied via the flat portion onto the information recording disc. The light flux emitted from the light source is incident from the spherical portion via an optical element such as a condenser.

In this information recording/reproducing apparatus, the information recording disc is used in such a manner that the distance between the flat surface of the SIL and

a surface portion facing to the SIL is not greater than the wavelength of the light flux for recording/reproducing. In order to maintain such a small distance between the SIL and the information recording disc, the distance between the SIL and the information recording disc is measured and the measurement result is fed back for servo operation for moving the SIL, or as shown in Fig. 12, the SIL 10 is mounted on a slider member 11 used in a hard disc and the SIL 10 is made to face the information recording disc, so that the SIL 10 is maintained at a predetermined distance from the information recording disc by an air gap formed between the information recording disc and the slider member by rotation of the information recording disc.

In a so-called near-field region where the distance between the flat portion of the SIL and the surface of the information recording disc is equal to or less than the wavelength of the light flux for recording/reproducing, an evanescent light is caused from the SIL to the information recording disc and a light flux is applied to the information recording disc.

In the aforementioned information recording disc and the information recording/reproducing apparatus according to the present invention, the anti-reflection coating layer of the information recording disc has an effect to suppress the aberration for the medium, which facilitates a wide recording margin and dust is not easily generated.

Furthermore, in the calculation result of the MTF (modulation transfer function), deterioration is little even when the air gap between the SIL and the

information recording disc increases its thickness. That is, when the information recording disc has a surface coated with an anti-reflection coating, deterioration of the MTF can be drastically improved as shown in Fig. 14, Fig. 15, and Fig. 16.

Moreover, in the phase change type optical disc, although the phase condition is important, only a small affect is observed in relation to the phase change and the reproduction margin is wide as shown in Fig. 17.

Furthermore, in a single-layered coat made from only SiO_2, as shown in Fig. 18 and Fig. 19, deterioration of the MTF can be suppressed. In the case of the phase change type optical disc in which the phase condition is also important, an excessive sensitivity in relation to the phase change is observed as shown in Fig. 20 causing a problem in a practical use but the MTF characteristic is preferable.

That is, when using a phase-change type medium, the condition of use is strict but when using a magneto-optical (MO) material, a single-layered coating film is sufficient.

It should be noted that even a three-layered coat consisting of SiO_2, SiN, and SiO_2 has no effect to suppress deterioration of the MTF if under a condition other than the anti-reflection condition as shown in Fig. 21, Fig. 22, and Fig. 23.

In the information recording disc according to the present invention, the air gap between the SIL and the information recording disc is assumed to be a thin film and for a light flux incident from the SIL, an anti-reflection coating is arranged on the enhancement layer, i.e., the reflection film, the second dielectric film, the signal

recording layer, and the first dielectric film, thereby facilitating the design method.

It should be noted that the object of the present invention is to increase the efficiency of the optical connection in a recording medium of a configuration not having a cover layer as well as to facilitate production of the recording medium. The present invention is not to be limited to an information recording disc and an information recording/reproducing apparatus employing the so-called near-field technique.

As has been described above, in the information recording disc and the information recording/reproducing apparatus according to the present invention, the information recording disc has a surface coated by the anti-reflection coating and accordingly, the first dielectric film can have a low reflectance for light rays of a wide range of the incident angle and it is possible to obtain a high coupling efficiency which changes gently against a change of the air gap thickness.

Moreover, the outermost surface opposing to the focusing element is made from SiO_2. Accordingly, even when the focusing element collides into the outermost surface, the signal recording layer weak to oxidization will not be easily exposed.

Furthermore, since the outermost surface is made from a thick SiO_2 film, it is possible to perform burnishing. Accordingly, it is possible to remove any protrusions formed due to an abnormal discharge in the sputtering step during a film formation of the signal recording layer. In this case, since the fifth dielectric film serving as the outermost surface has a thickness not less than 100 nm, a gentle margin is available

in burnishing.

When the focusing element collides into the surface portion and a peel-off is caused, the data loss is caused only in the portion where the anti-reflection coating has been peeled off, which is significantly smaller than the case when the anti-reflection coating film is formed on the side of the focusing element and the film is peeled off.

The anti-reflection coating of the information recording disc has an effect to suppress aberration for the medium, which facilitates the recording margin to become wider and no rubbish is easily generated.

Furthermore, the calculation result of the MTF (modulation transfer function) shows that even when the air gap between the focusing element and the information recording disc increases its thickness, deterioration is small. That is, the anti-reflection coating on the surface of the information recording disc significantly suppresses deterioration of the MTF.

Moreover, in the case of the phase change type optical disc, the phase change does not affect much and a wide reproduction margin is available.

That is, the present invention enables to provide an information recording disc having a sufficient margin for the change of the thickness of the air gap between the focusing element and an information recording disc when recording/reproducing an information signal using the so-called near-field technique. Even when a collision with the focusing element occurs, it is possible to minimize the data loss. The information recording disc has a film configuration which can easily be formed.

Furthermore, the present invention enables to provide an information recording/reproducing apparatus for recording/reproducing an information signal using the aforementioned information recording disc and using the so-called near-field technique, the apparatus having a sufficient margin for the thickness change of the air gap between the information recording disc and the focusing element. Moreover, even when the information recording disc collides into the focusing element, the apparatus can minimize the data loss.